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RESEARCH MEMORANDUM

FLIGHT MEASUREMENT OF AERODYNAMIC LOADS AND MOMENTS ON AN EXTERNAL STORE MOUNTED UNDER THE WING OF A SWEPT-WING FIGHTER-TYPE AIRPLANE

By Thomas C. O'Bryan

Langley Aeronautical Laboratory
Langley Field, Va.

NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS
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FLIGHT MEASUREMENT OF AERODYNAMIC LOADS AND MOMENTS ON AN EXTERNAL STORE MOUNTED UNDER THE WING OF A SWEPT-WING FIGHTER-TYPE AIRPLANE

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SUMMARY

A flight investigation of external-store characteristics has been conducted by the National Advisory Committee for Aeronautics with the use of a 245-gallon external fuel tank mounted under the wing of a North American F-86A airplane. The external-store normal- and side-load distributions were measured by means of an integrating pressure system at three Mach numbers $(M = 0.55, 0.75, \text{ and } 0.83)$ for a range of airplane lift coefficient up to the attainment of heavy buffeting. The results are presented in the form of load-coefficient distributions and their corresponding over-all force and moment coefficients.

It was found that store normal force increases abruptly on penetration of the buffet boundary. The increase in normal force occurred principally on the rear of the store resulting in an abrupt increase in store nose-down pitching moment.

The maximum value of store side force was of the same order of magnitude as the maximum value of store normal force. Side forces on the pylon supporting the store were found to be small.

INTRODUCTION

The wide use of external stores on modern aircraft with their effect on performance has evoked interest in the aerodynamic loads and moments on stores. The most common use of external stores is as external fuel tanks and rockets and bombs to increase the range and combat effectiveness of airplanes.

There is information available from wind-tunnel investigations reporting over-all force and moment measurements on stores mounted both on the wing tip and at several spanwise locations under a straight wing such as reference 1. Some detailed information on load distributions, as well as over-all force and moment measurements for a store mounted under a swept wing can be found in references 2 and 3.

The National Advisory Committee for Aeronautics has conducted a flight investigation of the aerodynamic loads and moments on a 245-gallon auxiliary fuel tank mounted under the wing of a North American F-86A airplane. The loads information was obtained as part of a buffeting investigation being conducted on external stores. It is the purpose of this report to present flight measurements of the load distribution and the integrated force and moment coefficients on this store to show the characteristics of the aerodynamic loading.

Flight measurements of aerodynamic loads and moments on the store were obtained throughout the Mach number and lift-coefficient range of the airplane. This report presents measurements at three selected Mach numbers ($M = 0.55$, 0.75, and 0.83) for an airplane lift-coefficient range up to the attainment of heavy buffeting.

SYMBOLS

A_s area represented by each pressure measurement on store and stabilizing fins (that part of total projected area in plane normal to measurement included between lines lying midway between the stations)

A_p area represented by each pressure measurement on pylon (that part of total projected area in plane normal to measurement included between lines lying midway between the stations)

a_n airplane normal acceleration

b wing span of airplane

c pylon chord in the stream direction

$\bar{c}$ mean aerodynamic chord of airplane wing

c_{n_s} section normal-load coefficient on store and stabilizing fins, $\dfrac{p_{U_{av}} - p_{L_{av}}}{q_0}$

c_{y_s} section side-load coefficient on store, $\left(\dfrac{p_{IB_{av}} - p_{OB_{av}}}{q_0}\right)_{Store}$

c_{y_p} section side-load coefficient on pylon, $\left(\dfrac{p_{IB_{av}} - p_{OB_{av}}}{q_0}\right)_{Pylon}$

C_{N_s} normal-force coefficient on store plus stabilizing fins, $\dfrac{\Sigma\left(c_{n_s}A_s\right)}{S}$

C_{Y_s} side-force coefficient on store, $\dfrac{\Sigma\left(c_{y_s}A_s\right)}{S}$

C_{Y_p} side-force coefficient on pylon, $\dfrac{\Sigma\left(c_{y_p}A_p\right)}{S}$

C_{m_s} pitching-moment coefficient on store plus stabilizing fins

C_{n_s} yawing-moment coefficient on store

C_{n_p} yawing-moment coefficient on pylon

C_L airplane lift coefficient, $\dfrac{Wa_n}{q_0 S}$

D_{max} maximum diameter of store

h_p maximum vertical dimension of pylon at any longitudinal station

h_s maximum vertical dimension of store at any longitudinal station

l_p longitudinal dimension of pylon

l_s longitudinal dimension of store

p local static pressure

p_o free-stream static pressure

P	pressure coefficient, $\frac{p - p_0}{q_0}$
$p_{U_{av}}$	average pressure over upper circumference at any cross-section measuring station
$p_{L_{av}}$	average pressure over lower circumference at any cross-section measuring station
$p_{IB_{av}}$	average pressure over inboard circumference at any cross-section measuring station
$p_{OB_{av}}$	average pressure over outboard circumference at any cross-section measuring station
q_0	free-stream dynamic pressure
S	plan-form area of airplane wing
t	maximum thickness of pylon
W	weight of airplane
w_p	maximum transverse dimension of pylon at any longitudinal station
w_s	maximum transverse dimension of store at any longitudinal station
x	longitudinal distance from nose of store
y	lateral distance from airplane center line to store location

APPARATUS AND PROCEDURE

The external store was mounted under the 35° sweptback wing of a North American F-86A airplane at 44 percent semispan as shown by the photograph in figure 1. Pertinent airplane characteristics and the ordinates of the store and pylon are presented in table I. Dimensioned drawings of the airplane and store installation are presented as figures 2 and 3.

The store is a 245-gallon auxiliary fuel tank (limited to carry only 206 gallons of fuel) manufactured by North American Aviation, Inc. The shape of the tank is generally elliptical and it has a fineness ratio of approximately 5.0. Small horizontal stabilizing fins are installed on the tail of the tank.

The primary mounting point of the tank is a tension fitting located near the tank center of gravity. Restraining fittings to prevent lateral and pitching motions are located ahead of and behind the main support. These supports are enclosed by a fairing having a maximum thickness ratio of 5 percent. The fairing will be referred to subsequently as the pylon. A compression strut, known as a sway brace, is located on each side of the tank near its center of gravity to provide restraint to lateral and rolling motions.

An integrating pressure system was used to obtain section normal- and side-load coefficients at a number of stations on the tank and its components, as shown in figure 4. The integrating pressure system, as applied to the determination of normal-force measurement at one cross-section of the tank, measures the differential between the average pressure over the upper and lower circumference of the section. Orifices representing equal segments of the diameter of the section were manifolded together to give the average pressure over the upper circumference of the section. Average pressure over the bottom circumference of the cross-section was obtained in the same manner. The measurement of normal-load distribution was obtained at nine different stations on the tank, and at five other stations on the fins. A similar type of system utilizing separate sets of orifices was used to measure the side-load distribution at the nine stations on the tank, plus six stations on the pylon. The integrating pressure system has been checked and found to give a good approximation of the average pressure for this type of installation.

Two pressure belts were installed on the lower surface of the wing, one on each side of and parallel to the pylon. The belts had static-pressure orifices distributed chordwise along their length from which pressure distributions on the lower surface of the wing adjacent to the pylon were obtained.

A tuft study of the air flow about the instrumented tank was made by using a 16-millimeter camera installed in the tank on the opposite wing. Another 16-millimeter camera was installed in the fuselage to obtain a tuft study of the upper surface of the wing.

Flight measurements of aerodynamic loads and moments on the store were obtained throughout the Mach number and lift-coefficient range of the airplane. The data were obtained in a combination of wind-up turns and shallow dives at approximately 30,000 feet pressure altitude. This report presents measurements at three selected Mach numbers ($M = 0.55$, 0.75, and 0.83) for airplane lift coefficients up to the attainment of heavy buffeting. The store loading at the three Mach numbers selected is representative of the loading encountered throughout the Mach number range of the airplane. A limited amount of the data in this report was presented in reference 4.

A nose-boom airspeed installation of the same type as that described in reference 5 was used to measure the airplane impact pressure and atmospheric pressure. Airplane impact pressure, atmospheric pressure, normal acceleration, and the differential pressure at each of the integrating pressure stations were recorded by standard NACA recording instruments.

RESULTS AND DISCUSSION

Normal- and Side-Load Distribution

Curves showing variation of normal- and side-load coefficients at each station on the store and its components at $M = 0.55$, 0.75, and 0.83 for two representative lift coefficients are presented in figures 5, 6, and 7. The store for which the results are presented was mounted under the right wing of the airplane. A force to the right is hereinafter referred to as an outboard load, and a force to the left as an inboard load.

Distributions of section normal-load coefficients over the store and horizontal fins in the presence of each other are presented in figure 5. The effect of an increase in airplane lift coefficient at each Mach number is seen to increase the up load on the nose and tail of the store. The up load on the nose is to be expected from the consideration of the variation in loading of a body alone as its angle of attack is increased. The marked increase in up load on the rear of the store and horizontal fins results principally from increased lift on the fins due to increased angle of attack. The distributions at $M = 0.55$ and 0.75 indicate little effect of Mach number. At $M = 0.83$ there is a reduction in over-all up load.

Distributions of section side-load coefficients on the store (fig. 6) at $M = 0.55$ and 0.75 are characterized by a region of inboard loading over the center of the store that decreases in magnitude as the airplane lift coefficient is increased, while at the same time the location of the peak of this inboard loading shifts rearward. The distributions at $M = 0.83$, although not showing as large a variation in loading with airplane lift coefficient as at lower Mach numbers, do indicate a trend in the same direction as the lift coefficient increases. The magnitude of the peak inboard loading in the distribution increases as Mach number is increased.

Distributions of section side-load coefficient on the store and pylon at $M = 0.83$ for several airplane lift coefficients were not obtained as the pressure measurement at several stations on the store and pylon exceeded the range of the recording instruments because of the use of more sensitive pressure cells for most of the flights in order to determine more accurately the pressures at low Mach numbers.

Side-load-coefficient distributions on the pylon (fig. 7) reflect the side loading on the store. The load varies from outboard near the leading edge to inboard near the midchord. The rearward shift in the peak inboard loading that occurred in the store side-load distribution is also present in the pylon loading.

The pressure distributions obtained from pressure belts located on the lower surface of the wing on each side of the pylon (fig. 8) reflect the changes in side load on the store and pylon. Extrapolation of the distributions to the leading edge of the pylon indicates a pressure differential between the inboard and outboard belt that produces an outboard load on the pylon near its leading edge. The pressure differential between the belts in the region just behind the leading edge of the pylon produced a region of inboard loading on the pylon.

Integrated Force and Moment Coefficients

Force characteristics.- Integrated force coefficients were obtained by summation of the product of section load coefficients and the area represented by the measurement divided by the wing plan-form area (288 square feet). The area represented by each measurement is that part of the total projected area in the plane normal to the measurement included between lines lying midway between the stations.

Normal-force coefficients for the store plus fins are presented in figure 9 as a function of airplane lift coefficient for the three Mach numbers selected. The maximum up load on the store at $M = 0.83$ $\left(C_{N_s} = 0.010\right)$ at 30,000 feet altitude is approximately 65 percent of the weight of the total fuel load capacity of the store. Comparison of the variation of store normal-force coefficients at $M = 0.55$ with the variation at $M = 0.75$ indicates a very similar loading. The only significant difference between these two Mach numbers is that the airplane lift coefficient at which the force increases rapidly is higher for $M = 0.55$. The normal-force coefficients at $M = 0.83$ indicate a loading that varies gradually from a small down load to an up load as the airplane lift coefficient is increased up to a value at which the force break on the store occurs.

The force break occurred at the value of airplane lift coefficient at which airplane buffeting occurred for all Mach numbers. Inspection of pressure records and study of tuft pictures indicated that separation occurred on the upper rear quadrant of the store at $M = 0.83$ for all values of lift coefficient below the force break. No separation was evident on the store at the lower Mach numbers for values of airplane lift coefficient below the force break. For values of lift coefficient above the force break, at all three Mach numbers, no separation on the store was evident from the tuft pictures; however, the pressure records evidenced small amplitude oscillations. Tuft pictures indicated widespread separation on the upper and lower surface of the wing in the range of airplane lift coefficient above the force break. Some of the scatter observed in the data at $M = 0.83$ is due to the uncertainty in estimating the average value of the oscillating pressure.

Integrated normal-force coefficients for the store plus fins at $M = 0.55$ and 0.83 are compared with the coefficients for the store alone in the presence of the fins in figure 10. The store-alone data were obtained by integrating the section load coefficient of the store alone in the presence of the fins. The effect of the fins is shown to contribute a significant amount of the up load on the store for both Mach numbers throughout the range of airplane lift coefficients.

Integrated side-force coefficients on the store are presented in figure 11(a) as a function of airplane lift coefficient. The side-force coefficients indicate an inboard load that decreases smoothly as the airplane lift coefficient is increased without the break that occurred in normal force. The inboard loading on the store is increased as the Mach number increases. It should be noted that the maximum value of store side force is indicated to be of the same order of magnitude as the maximum value of store normal force. The side force for this installation may be of more importance than the normal force as it occurs in the plane of least structural strength.

Integrated side-force coefficients on the pylon (fig. 11(b)) indicate a small outboard load throughout the Mach number and lift-coefficient range presented. Reference to the side-force distribution on the pylon (fig. 7) shows that, although there is considerable variation in the shape of the side-force distribution, the regions of inboard and outboard load nearly balance each other.

Moment characteristics.- Pitching-moment and yawing-moment coefficients based on wing area and aerodynamic chord for the store and its components were taken about a point on the center line of the store which was the same distance behind the nose of the airplane as was the location of the quarter-chord point of the mean aerodynamic chord of the airplane. Pitching-moment coefficients for the store plus fins are presented in figure 12 as a function of airplane lift coefficient. The pitching moments are all nose down except for a small range of lift coefficient at $M = 0.55$. The maximum nose-down pitching moment at $M = 0.83$ $(C_{m_s} = -0.004)$ at 30,000 feet altitude is equivalent to shifting the center of gravity of the maximum fuel load in the store about 2 feet forward. The nose-down moments decrease as lift coefficient increases up to a value at which there is an abrupt increase in nose-down pitching moment. The abrupt nose-down pitching moment on the store at all Mach numbers occurs at the same value of airplane lift coefficient at which the normal-force break occurs on the store. Increasing Mach number from 0.55 to 0.83 increases the nose-down moment.

Pitching-moment coefficients for the store alone in the presence of the fins and the store plus fins is presented in figure 13 for $M = 0.55$ and 0.83. Comparison of the variation of the pitching-moment coefficients with and without fins indicates that the fins contribute a nose-down moment to the store throughout the range of airplane lift coefficient. The pitching-moment coefficients on the store in the presence of the fins do not exhibit the sharp increase in nose-down pitching moment that occurs on the store-plus-fins configuration at the force-break lift coefficient.

Yawing-moment characteristics on the store are presented in figure 14(a). An increase in airplane lift coefficient increases the magnitude of the yawing-moment coefficients such that the nose tends to yaw in an outboard direction, reflecting the rearward movement of the location of the peak inboard loading coefficient as seen in figure 6. The effect of Mach number on the yawing-moment coefficients is small.

Yawing-moment characteristics of the pylon are presented in figure 14(b). The moment coefficients are small and the nose tends to yaw in an outboard direction. There is no appreciable effect of Mach number or lift coefficient.

CONCLUDING REMARKS

Measurements of normal-load and side-load distributions, and their integrated force and moment coefficients have been made on an external store mounted under the wing of a North American F-86A airplane. The investigation was made for three Mach numbers $(M = 0.55, 0.75, \text{and } 0.83)$ for a range of lift coefficients up to the attainment of heavy buffeting.

It was found that store normal force increases abruptly on penetration of the buffet boundary. The increase in lift occurs principally on the rear of the store, resulting in an abrupt increase in store nose-down pitching moment.

The maximum value of store side force was of the same order of magnitude as the maximum value of store normal force. Side forces on the pylon supporting the tank were found to be small.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., July 8, 1953.

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1. Silvers, H. Norman, and King, Thomas J., Jr.: Investigation at High Subsonic Speeds of Bodies Mounted From the Wing of an Unswept-Wing—Fuselage Model, Including Measurements of Body Loads. NACA RM L52J08, 1952.

2. Fail, R., and Holford, J. F.: Preliminary Note on Low Speed Tunnel Model Tests of Pressure Distribution and Jettisoning of Strut Tanks on a 40° Swept Back Wing. Tech. Note No. Aero. 2095, British R.A.E., Mar. 1951.

3. Holford, J. F.: Preliminary Note on Low Speed Tunnel Model Tests of Pressure Distribution and Jettisoning of Strut Tanks on a 40° Swept Back Wing. Addendum: Further Pressure Plotting Tests. Tech. Note No. Aero. 2095b, British R.A.E., June 1952.

4. Silvers, H. Norman, and O'Bryan, Thomas C.: Some Notes on the Aerodynamic Loads Associated With External-Store Installations. NACA RM L53E06a, 1953.

5. Thompson, Jim Rogers, Bray, Richard S., and Cooper, George E.: Flight Calibration of Four Airspeed Systems on a Swept-Wing Airplane at Mach Numbers up to 1.04 by the NACA Radar-Phototheodolite Method. NACA RM A50H24, 1950.

TABLE I.- PERTINENT GEOMETRICAL PROPERTIES OF TEST AIRPLANE AND DIMENSIONS OF EXTERNAL STORE AND PYLON

Airplane

Total wing area, sq ft 287.9
Mean aerodynamic chord (wing station 98.71 measured normal to airplane center line), in. 97.03
Location of external store (measured normal to airplane center line), in. 99.5

External Store and Pylon

[All dimensions measured normal to store center line and normal to pylon center line, in.]

Store			Pylon		
l_s	$w_s/2$	$h_s/2$	l_p	$w_p/2$	$h_p/2$
3.6	6.0	4.0	3.4	3.0	3.7
14.6	10.8	8.8	13.4	2.0	3.0
29.2	14.1	12.4	25.2	2.0	2.5
51.1	15.8	13.5	40.2	2.0	2.5
73.0	15.6	13.4	53.6	2.0	3.0
94.9	13.7	11.5	63.6	0.3	4.0
116.8	10.1	8.2			
131.4	7.0	5.0			
142.4	3.9	2.0			

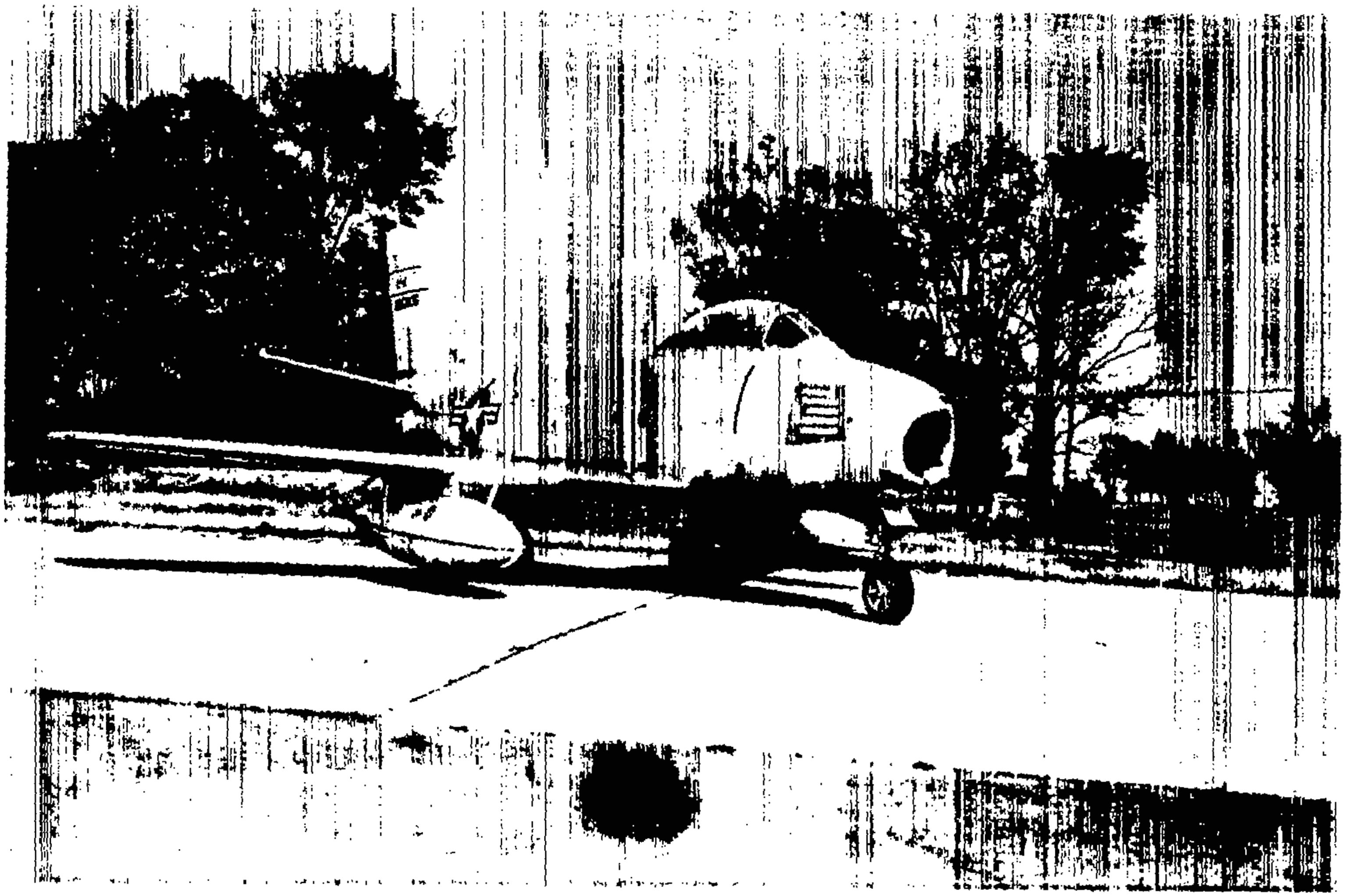

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Figure 1.- Photograph of North American F-86A airplane with 245-gallon external fuel tanks installed.

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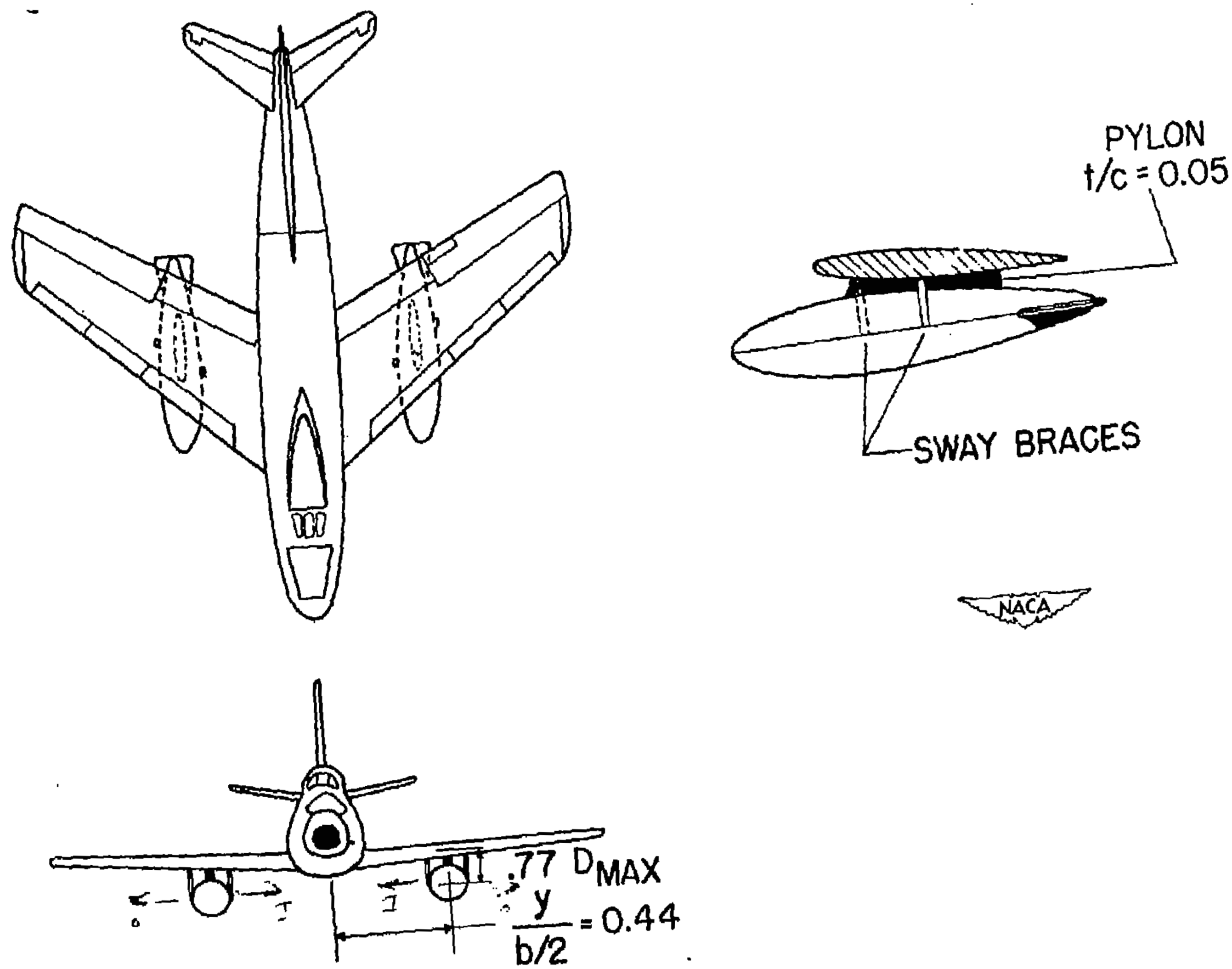

Figure 2.- Drawing of North American F-86A airplane showing details of external fuel-tank installation.

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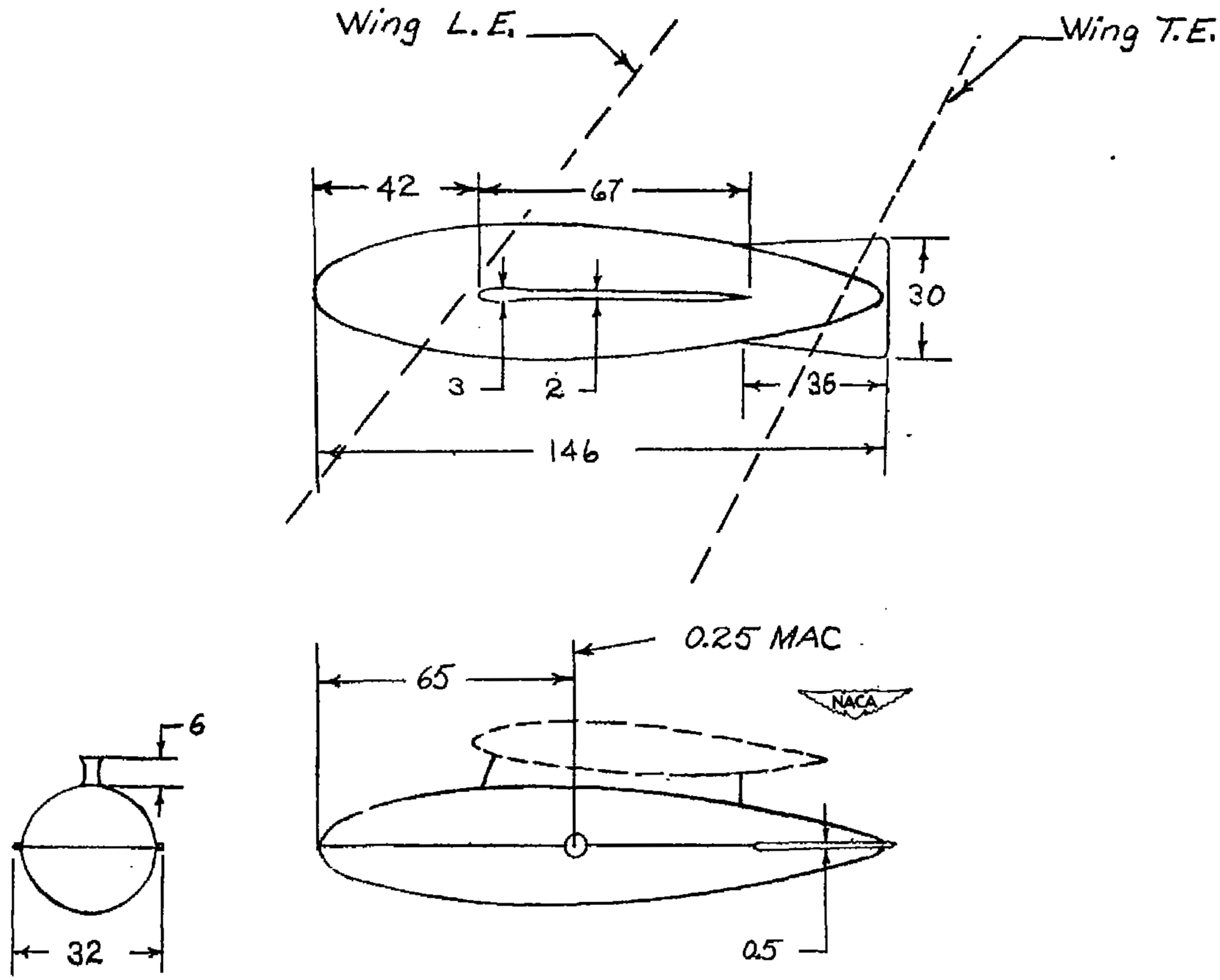

Figure 3.- Dimensioned drawing of external store. All dimensions are in inches.

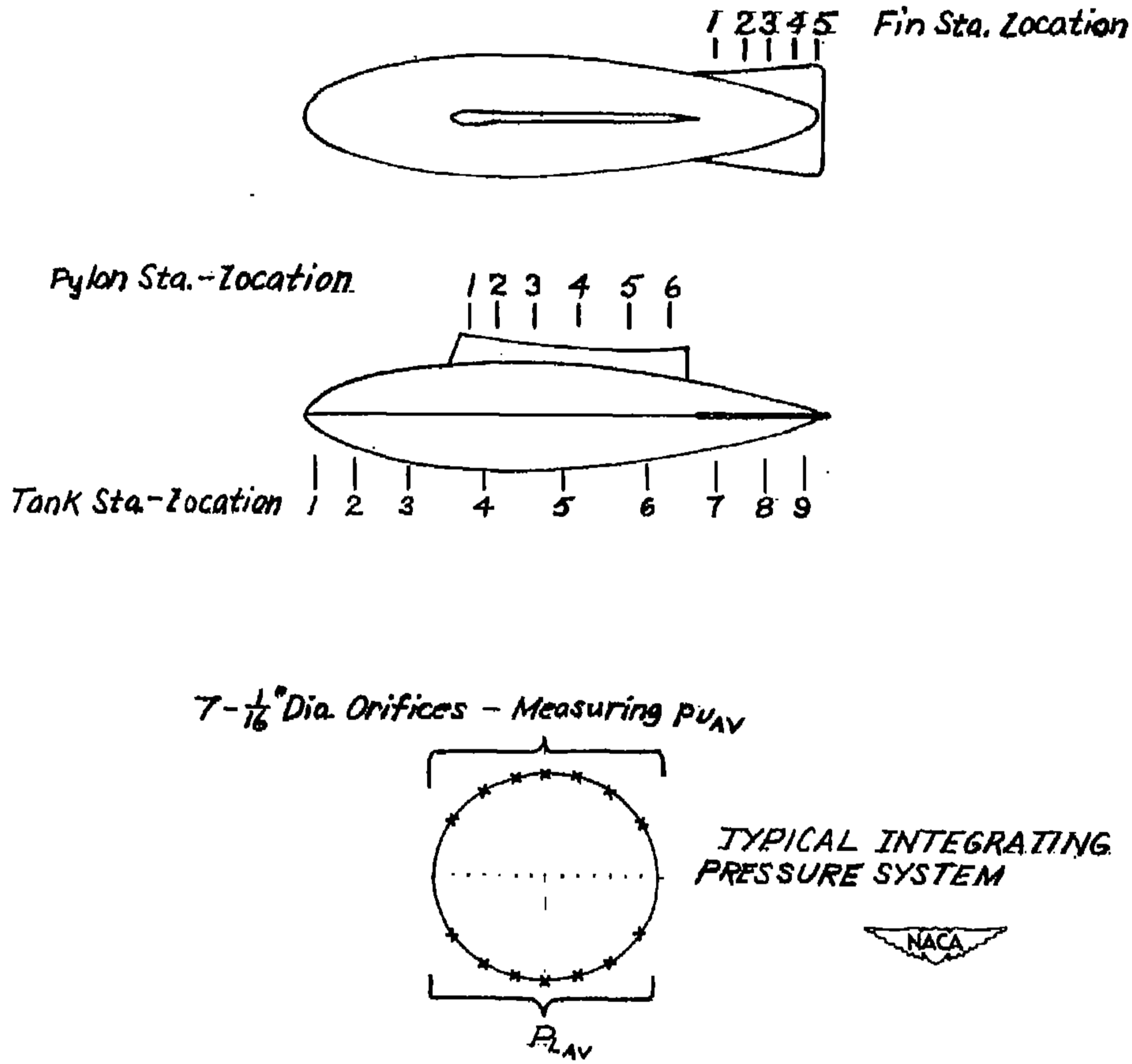

Figure 4.- Drawing of 245-gallon external fuel tank showing location of measuring stations and details of one typical measuring station.

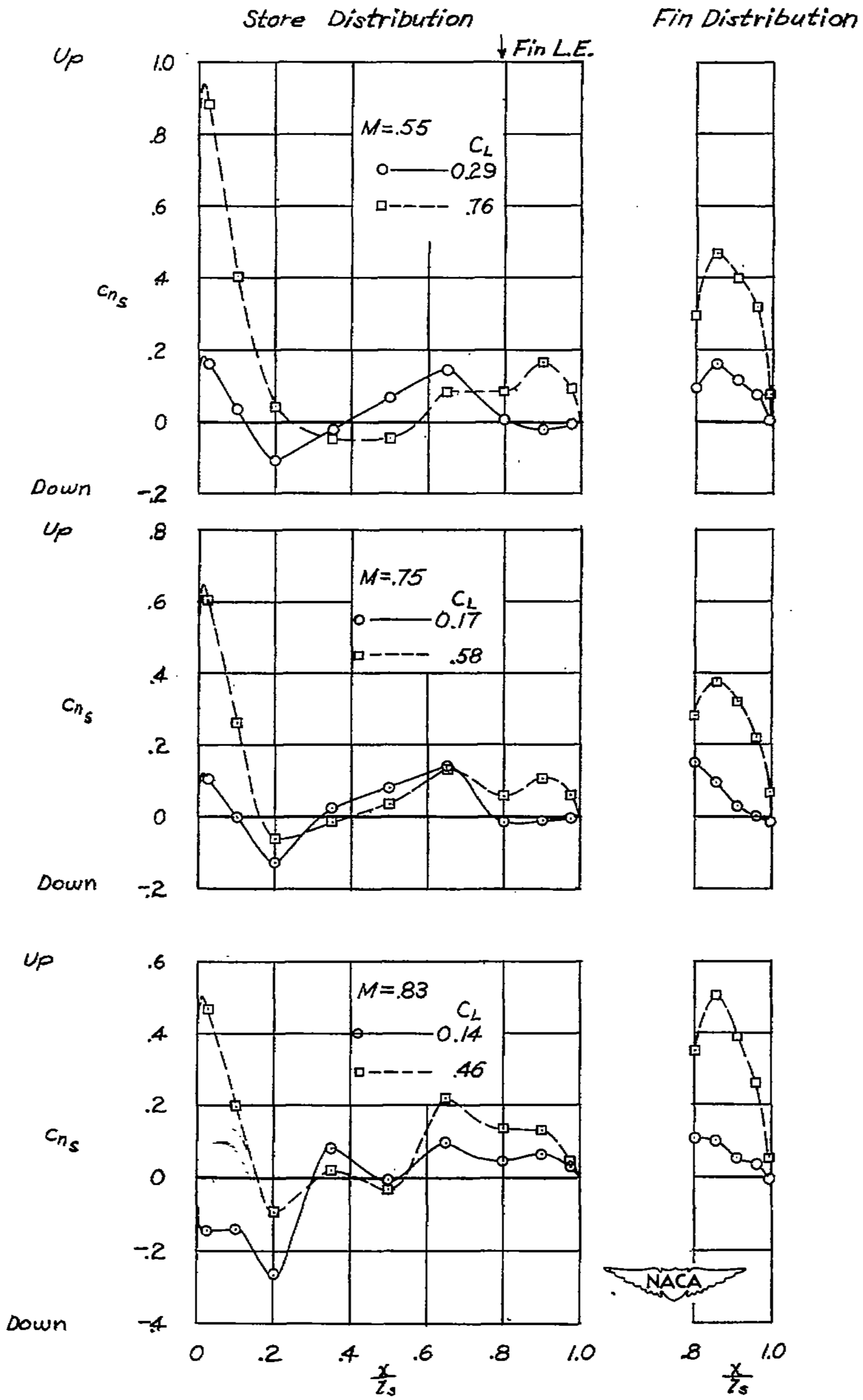

Figure 5.- Typical section normal-load coefficient distributions on external store and fins for three Mach numbers.

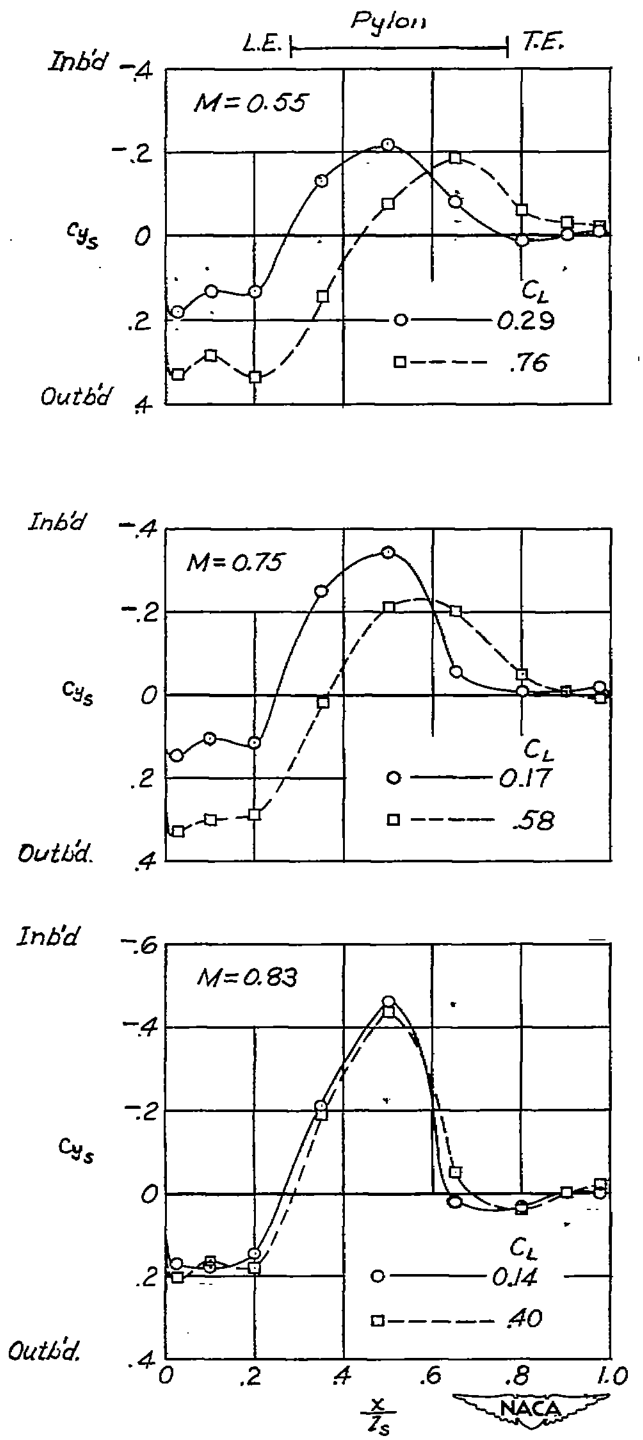

Figure 6.- Typical section side-load coefficient distributions on external store for three Mach numbers.

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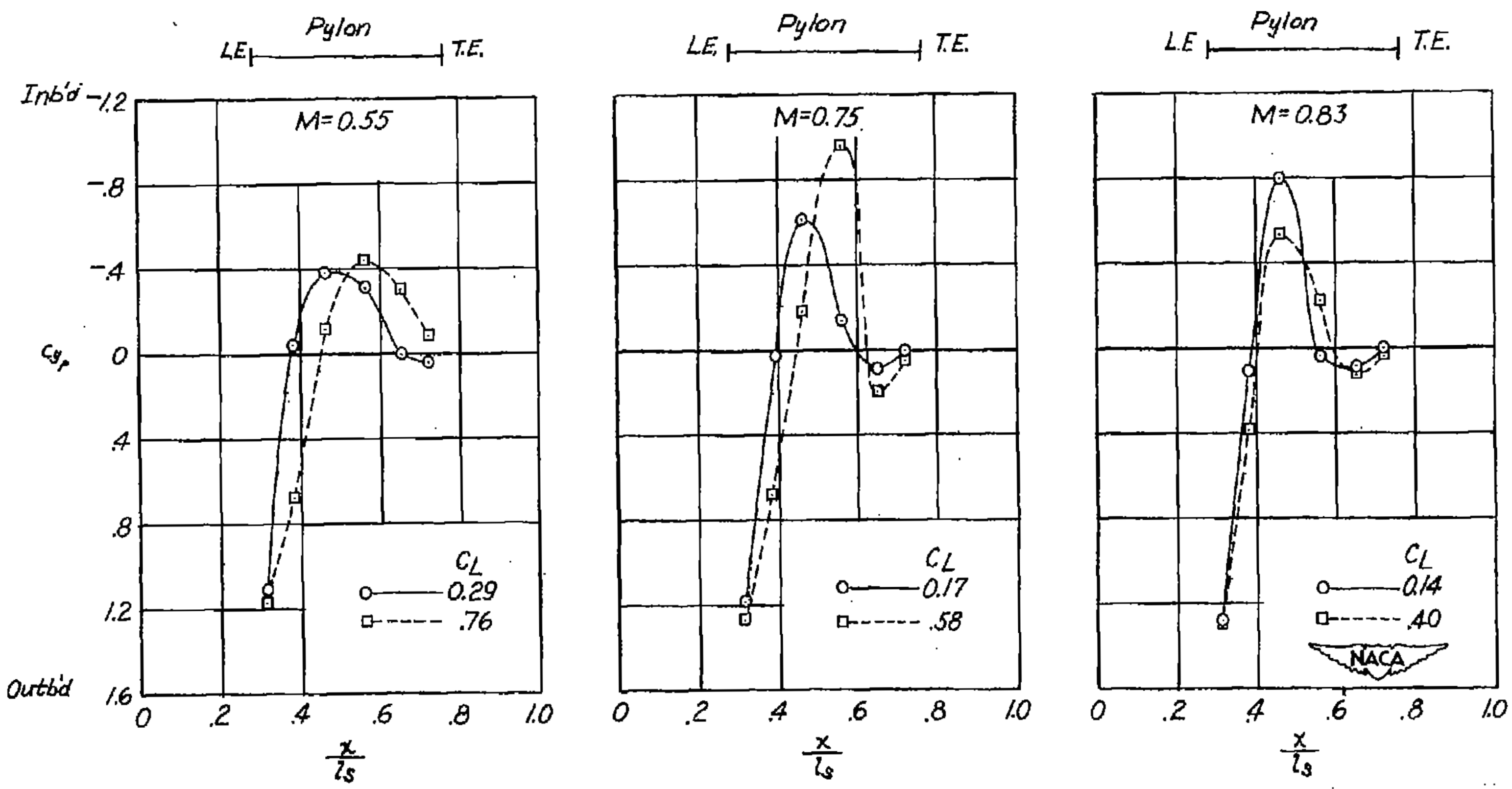

Figure 7.- Typical section side-load coefficient distributions on pylon for three Mach numbers.

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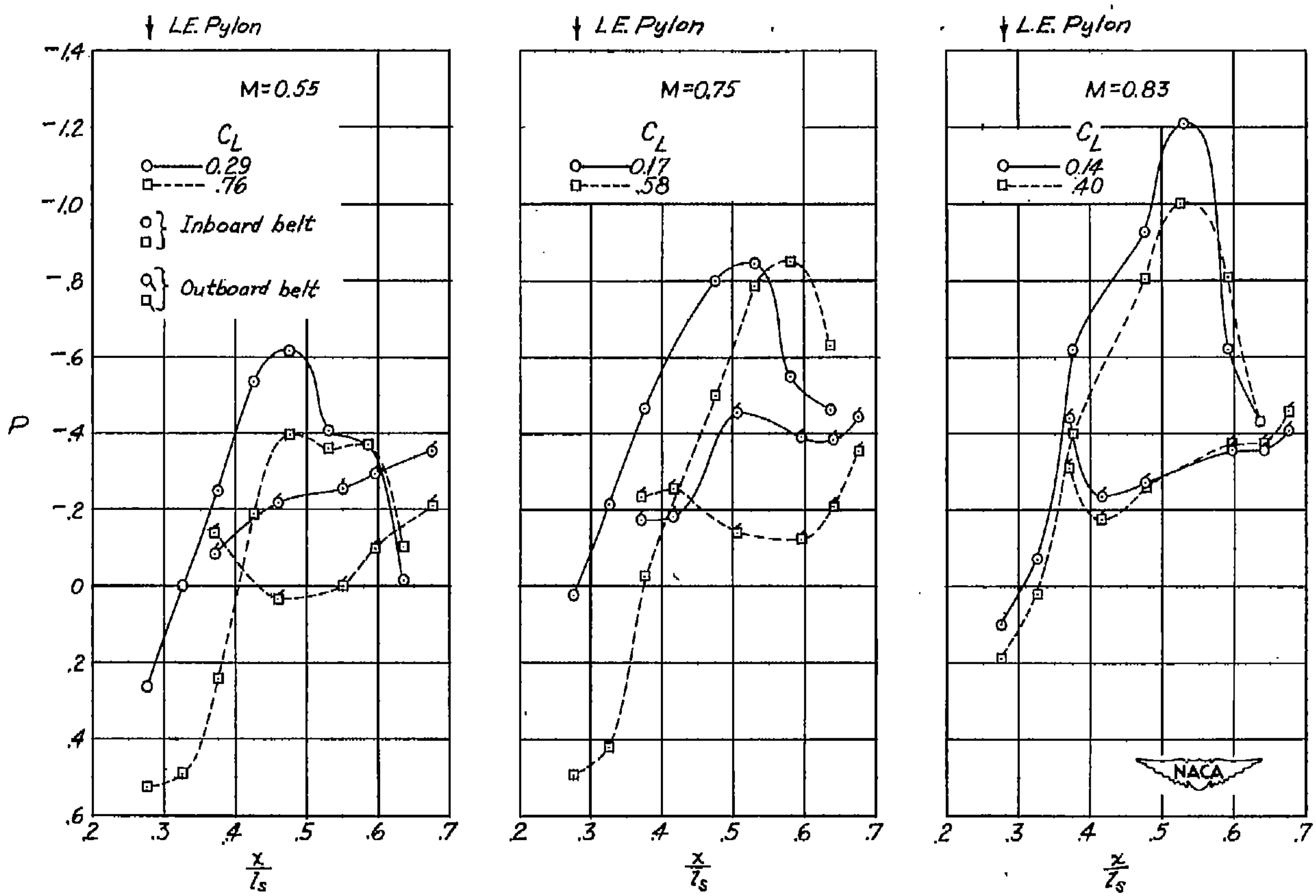

Figure 8.- Typical pressure distributions, on pressure belts located on each side of the pylon, for three Mach numbers.

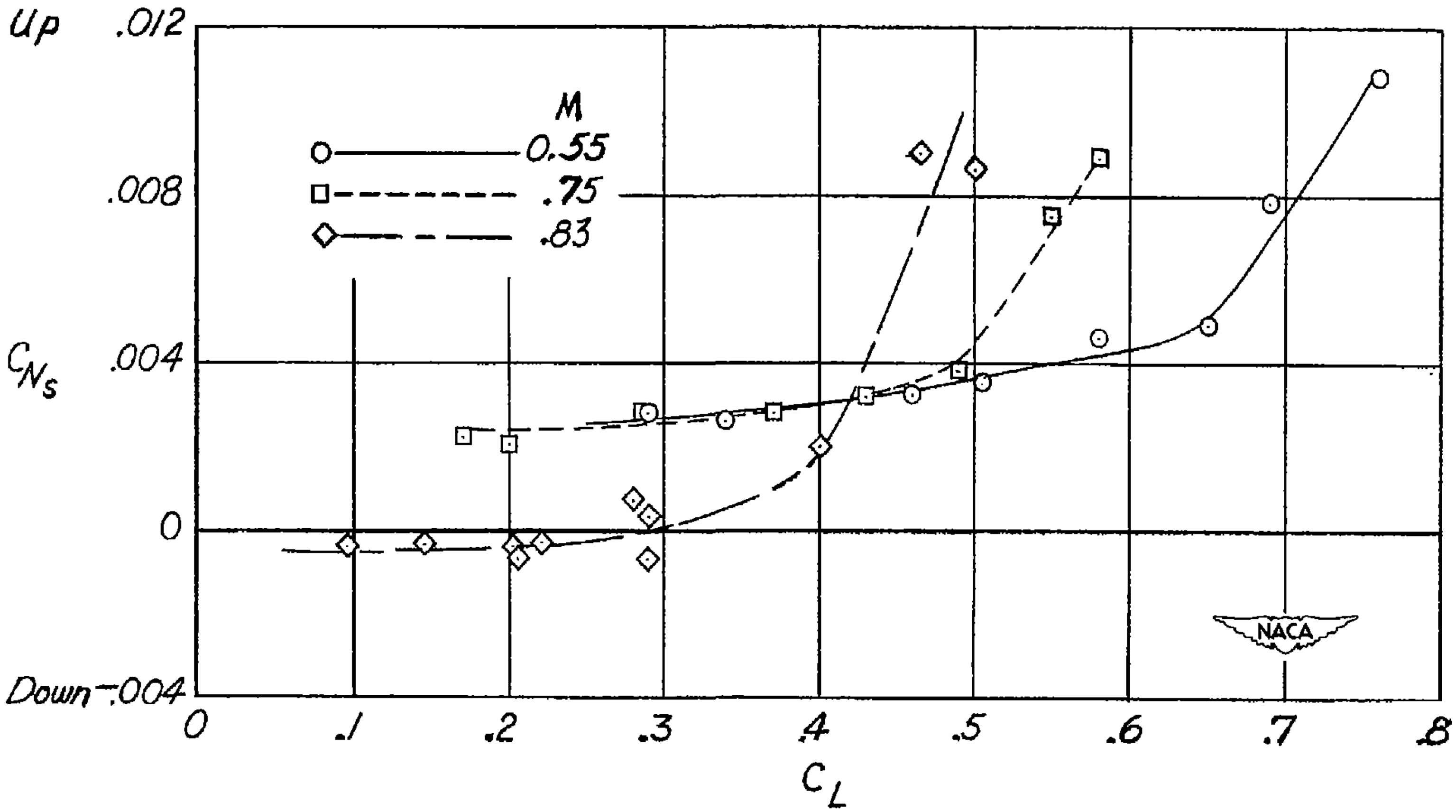

Figure 9.- Integrated normal-force coefficients on store plus fins for three Mach numbers.

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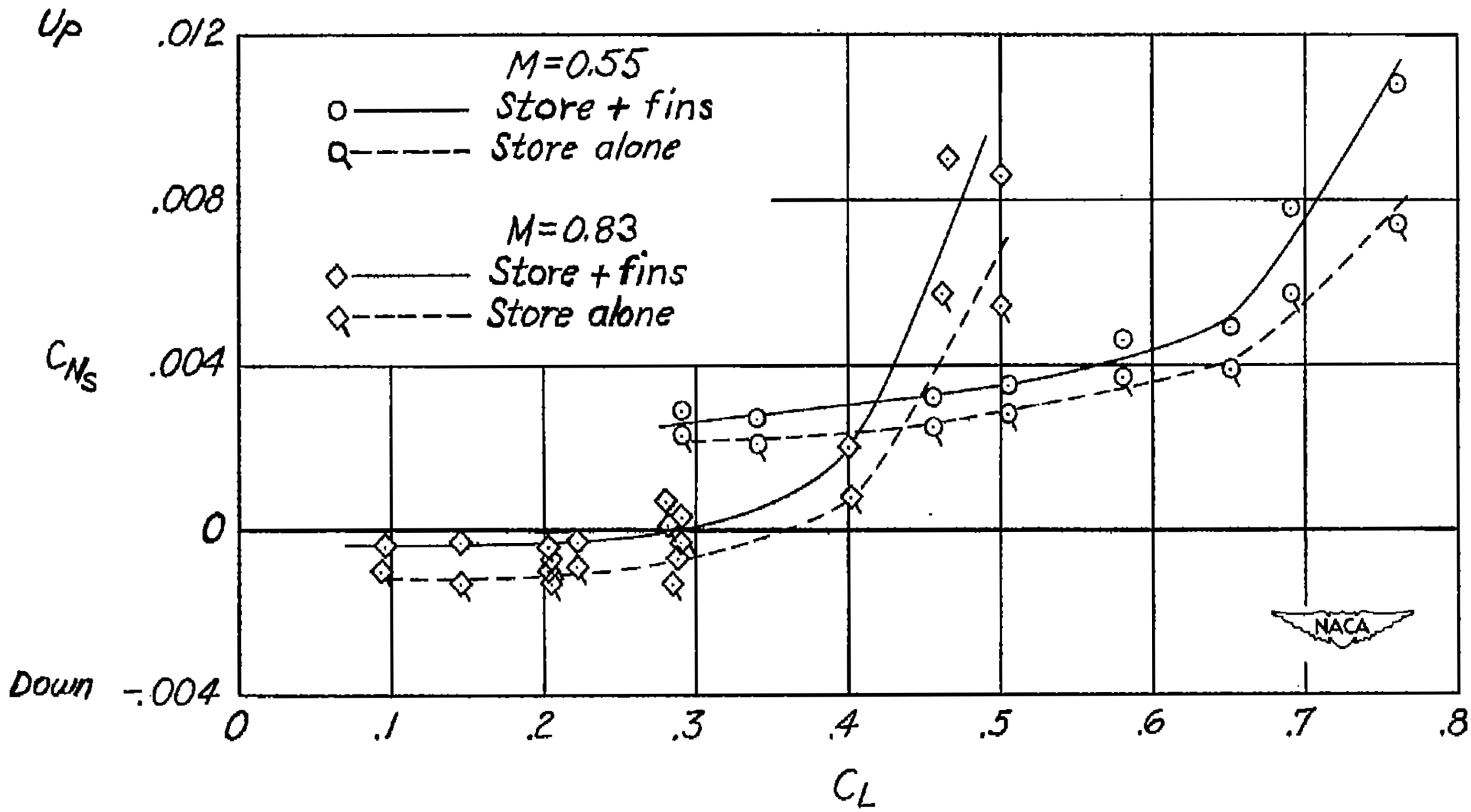

Figure 10.- Comparison of integrated normal-force coefficient on store plus fins and store in the presence of fins at M = 0.55 and 0.83.

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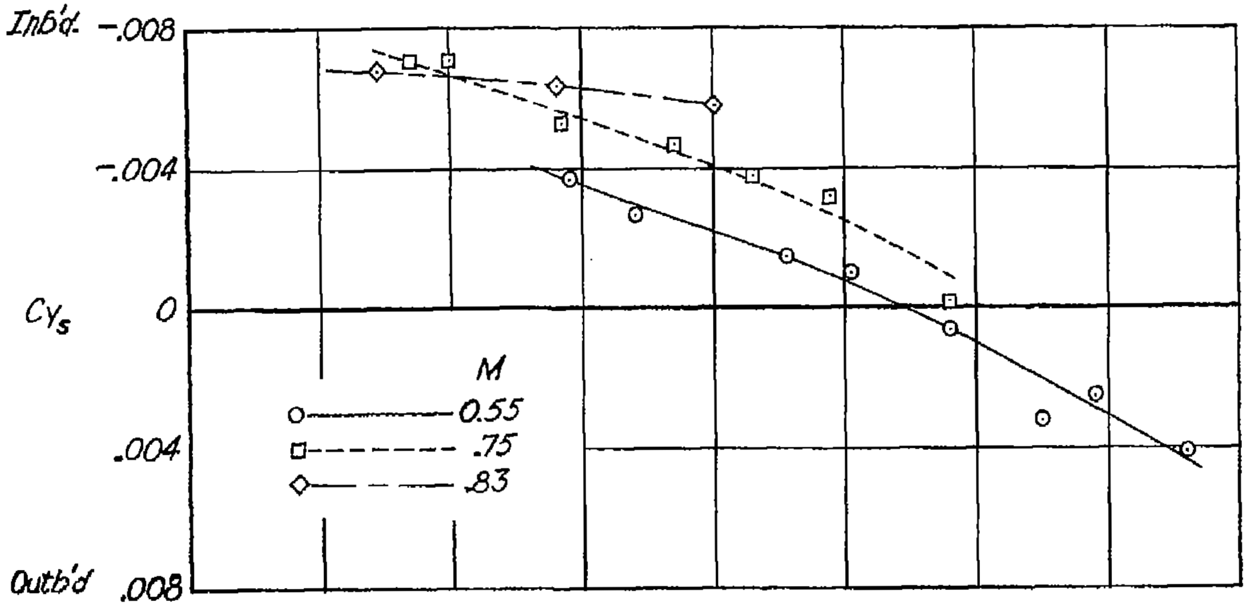
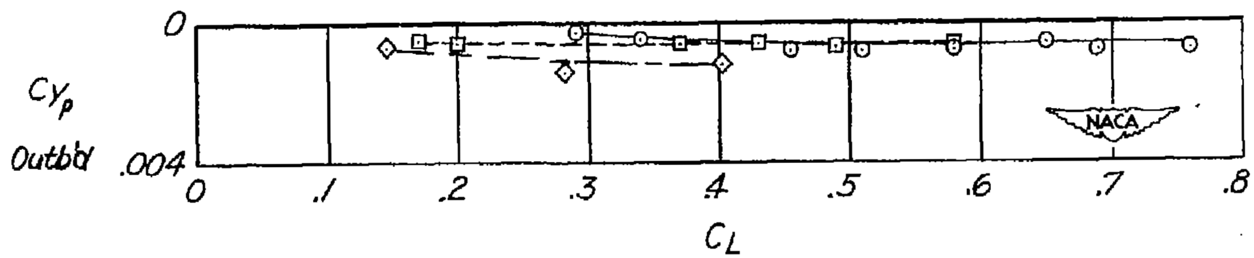


(a) Integrated side-force coefficients on store.



(b) Integrated side-force coefficients on pylon.

Figure 11.- Integrated side-force coefficients on store and pylon for three Mach numbers.

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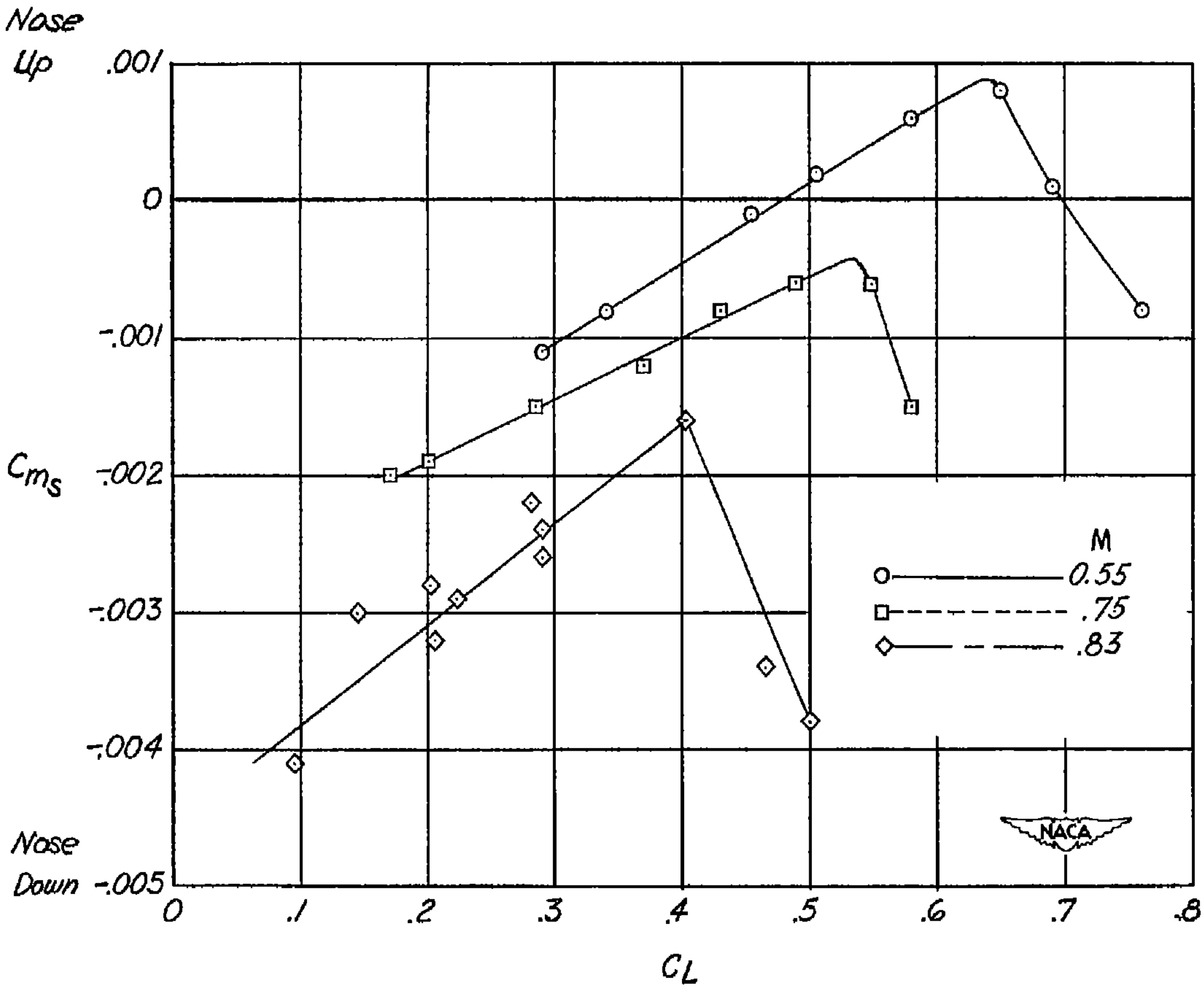

Figure 12.- Pitching-moment coefficients on store plus fins for three Mach numbers.

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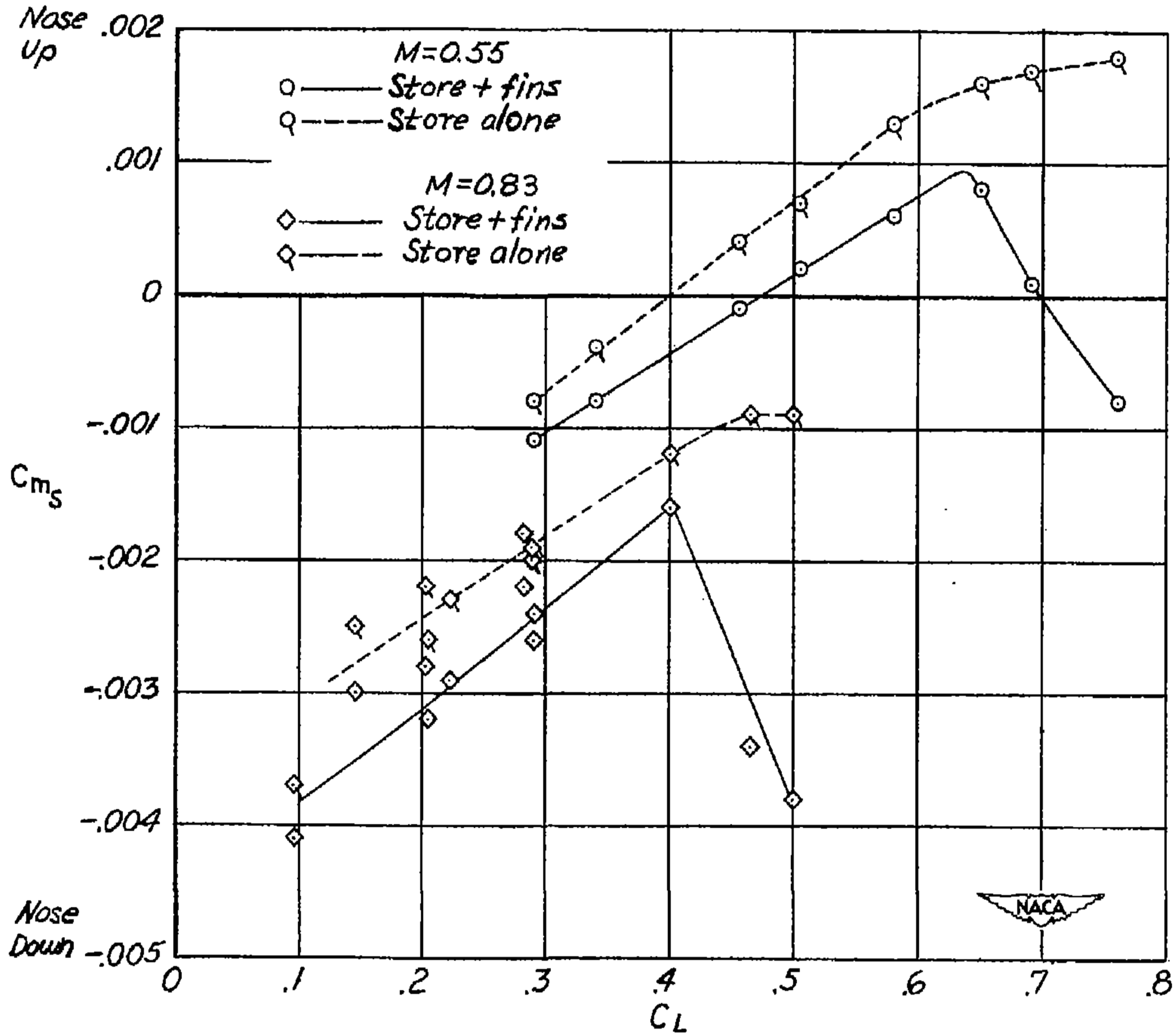

Figure 13.- Comparison of pitching-moment coefficients on store plus fins and store in the presence of the fins at M = 0.55 and 0.83.

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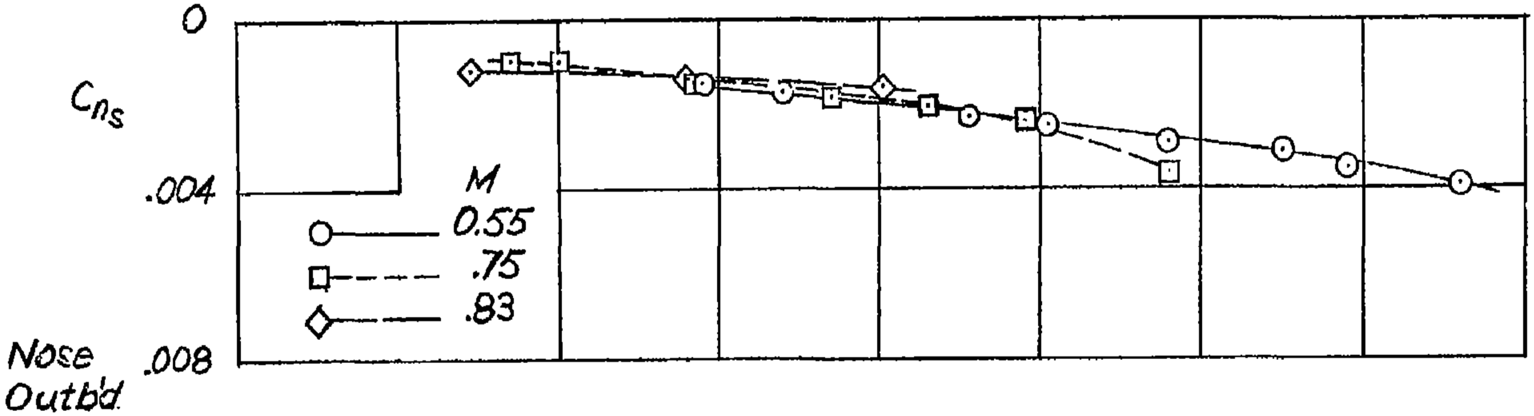

(a) Yawing-moment coefficients on store.

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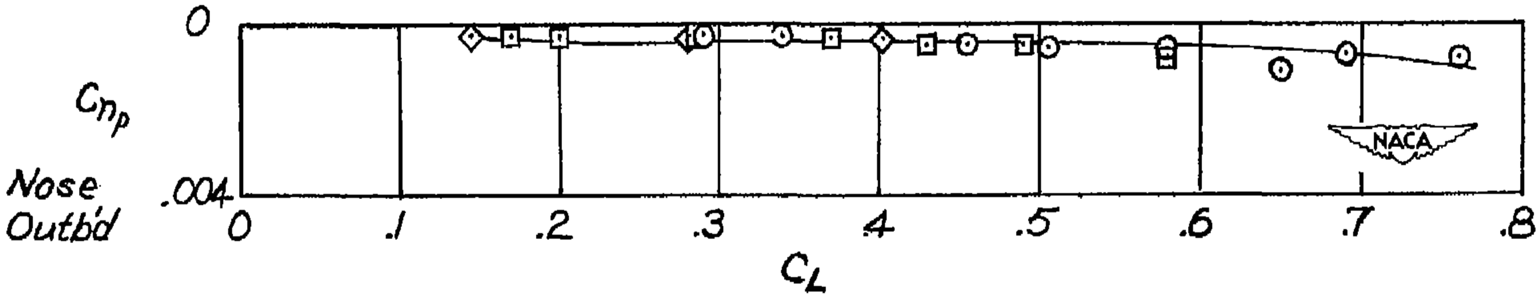

(b) Yawing-moment coefficients on pylon.

Figure 14.- Yawing-moment coefficients on store and pylon for three Mach numbers.